

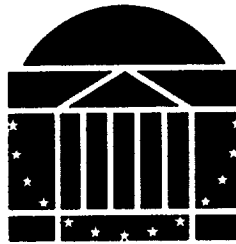
Dual-Mode Combustion

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Introduction

The Department of Mechanical and Aerospace Engineering at the University of Virginia has conducted an investigation of the mixing and combustion processes in a hydrogen fueled dual-mode scramjet combustor. The experiment essentially consisted of the "direct connect" continuous operation of a Mach 2 rectangular combustor with a single unswept ramp fuel injector. The stagnation enthalpy of the test flow simulated a flight Mach number of 5. Measurements were obtained using conventional wall instrumentation and laser based diagnostics. These diagnostics included, pressure and wall temperature measurements, Fuel Plume Imaging (FPI) and Particle Image Velocimetry (PIV). Figure 1 presents a schematic of the combustor configuration and a summary of the measurements obtained. The experimental work at UVa was parallel by Computational Fluid Dynamics (CFD) work at NASA Langley. The numerical and experiment results are compared in this document. The funding for this project partly or fully supported the following personnel at the University of Virginia: one (1) faculty member, one (1) professional research staff member, two (2) research consultants, two (2) machinists, three (3) graduate students and ten (10) undergraduate students.

Major accomplishments

Major accomplishments for the project are listed below and are fully described in the following pages:

- Demonstration of dual-mode operation of a hydrogen fuel scramjet at Mach 5 stagnation enthalpy
- Flow seeding apparatus developed for high enthalpy combustion studies
- Flow seeder performance assessed
- Fuel Plume Imaging (FPI) performed
- Particle Image Velocimetry (PIV) performed
- PIV error analysis performed
- PIV system upgraded to 3D capability
- Fuel plume temporal variation analyzed
- Pressure measurements compared with CFD results
- FPI measurements compared with CFD results
- PIV measurements compared with CFD results
- Schlieren system developed
- Chemiluminescence of flame analyzed
- High enthalpy wind tunnel facility maintained
- Results presented at major international conferences

Dual-mode Combustor Characterization Experiment

Data to resolve CFD uncertainty in predicted mixing and combustion

• PLIF

- OH concentration

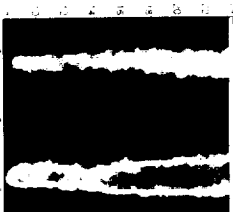
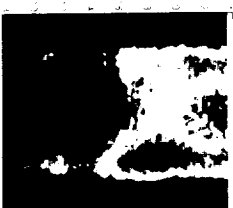
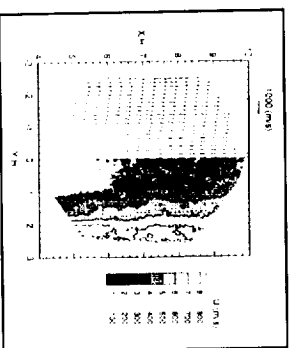
$Y/O = 1.00$

• Luminosity

• Video shadowgraph

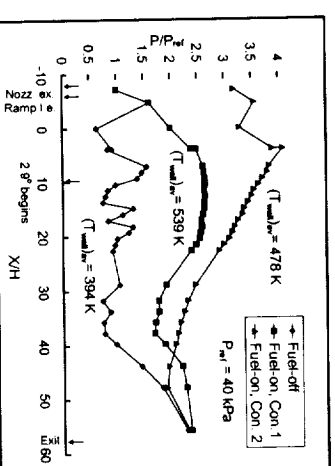
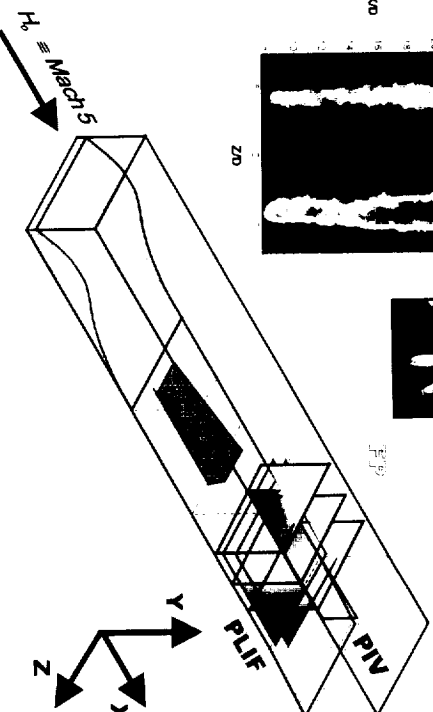
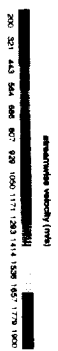
• Schlieren

- OH velocity



• Wall pressure and temperature

• PIV - velocity



• FPI mixing

Experimental

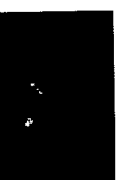
Computational

• FPI combustion

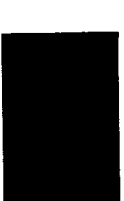
Experimental

Computational

X/H = 7



X/H = 7



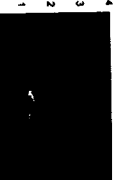
X/H = 5



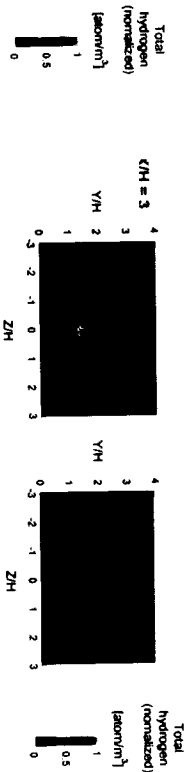
X/H = 5



X/H = 3



X/H = 3



Aerospace Research Laboratory
University of Virginia

Figure 1 Combustor schematic and summary of experimental measurements

Conference proceedings

Goyne CP, McDaniel JC, Krauss RH and Day SW, "Velocity Measurement in a Dual-mode Supersonic Combustor using Particle Image Velocimetry," AIAA/NAL-NASDA-ISAS 10th International Space Planes and Hypersonic Systems and Technologies Conference, AIAA 2001-1761, April 2001.

Goyne CP, McDaniel JC, Quagliaroli TM and Krauss RH, "Dual-Mode Combustion of Hydrogen in a Mach 5 Enthalpy, Clean-air, Continuous-flow Facility," 14th International Symposium on Airbreathing Engines, Italy, 1999.

Publications

Goyne CP, McDaniel JC, Quagliaroli TM, Krauss RH, and Day SW, "Dual-Mode Combustion of Hydrogen in a Mach 5, Continuous-Flow Facility," *Journal of Propulsion and Power*, Vol 17, No 6, 2001, pp. 1313-1318.

Goyne CP, McDaniel JC, Krauss RH and Day SW, "Velocity Measurement in a Dual-mode Supersonic Combustor using Particle Image Velocimetry," in review for *AIAA Journal*, 2002.